1937

The Posterior Median Aperture of the Fourth Ventricle of Human Adult and Fetal Brains

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THE POSTERIOR MEDIAN APERTURE OF THE FOURTH VENTRICLE

OF

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Introduction

Of recent years, Dr. Strong, head of the department of anatomy at Loyola University School of Medicine, has revived interest in aspects of the anatomy of the fourth ventricle of the mammalian brain, especially in relation to foramina communicating with the subarachnoid space. Historically we must return to the early part of the nineteenth century for the first description of an aperture(Magendie) related to the circulation of the cerebro-spinal fluid.

From that time on, there have been investigators who have attempted to prove the presence of a posterior median communication from the rhombencephalic ventricle. Lack of agreement is evident when one considers the precision necessary to present a correct view of the area in dispute. In fact, the problem may be stated briefly as a question, "are the foramina artefacts of dissection or do they normally exist?"

Under Dr. Strong's suggestion and supervision the fourth ventricle of human brains was studied from this standpoint. The gross dissections were mainly on adult specimens, while serial sections for permanent preservation were made of both fetal and adult brains.

One of our chief difficulties was to obtain human material suitable for study. Many excellent, adult brain

stems were procured, for which we are indebted to Dr. Jaffe of the Cook County Hospital. Gratitude is also due to Dr. Essenberg, of our Embryology department, for supplying the fetal heads for our studies. To the other members of our anatomy staff, Professor Job and Dr. Hughes, is due our appreciation for suggestions and criticisms offered at our Seminar meetings. Furthermore, we are grateful to Mr. Warren for his invaluable assistance with all technical details, especially when trying circumstances arose, also to Miss Bakehouse for the contribution as photographer.

Finally, it is the author's desire to acknowledge his obligation to Professor Strong for his supervision of the work.

Literature

The state of affairs, concerning the communications of the fourth ventricle, is well summarized by Sorrentino(14) who, in his discussion, cites such men as Reichert, Kolliker, Kruveilhier and Cannieu who report, postively, that any foramen found is due to post-mortem changes or because of tears affected at points of least resistance in the tela chorioidea. Furthermore he states that such anatomists as Luschka, Sappey, Retzius and others, believed in the presence of an indisputable foramen.

In passing over the work of others, one may gain a knowledge of what has been found thus far. Developmentally the work of Weed on pig and human embryos of different ages (16) is one of the more recent investigations of the roof of the fourth ventricle and the passage of the cerebro spinal fluid. His results showed that fifteen and one half millimeter human embryos were the first to show the region named the " area membranacea inferior " by Weed. However, even studies up to fifty-two millimeters,showed an intact membrane covering the roof of the fourth ventricle in the inferior portion. From this Weed concluded that foramina do not exist at the commencement of cerbrospinal circulation.

Keegan (8) and later Jessico (7) agreed with the findings of Weed. Keegan used many pig, sheep and several human embryos and described in a six millimeter pig, a thin, pavement cell, oval area in the roof of the fourth ventricle, which later became modified by the development of the transverse fold of the chorioid plexus and extended to the posterior limit of the chorioid plexus.

Jessico designates the tela chorioidea of the albino rat as the remains of a modified " area membranacea inferior ". In addition he observed the foramina of Luschka, in the nineteen day seventeen hour stage albino rat, appearing in the lateral recesses. In the fourteen day post-natal specimens all traces of the area membranacea were lost, and the entire roof consisted of the tela chorioidea with the chorioid plexus.

Wilder (17) in considering the metapore (foramen of Magendie) in man and in an orang quotes a manuscript communication by Professor C. S. Minot on the embryology of the foramen of Magendie. " It is an opening through the roof of the fourth ventricle. There are two possibilities: Either it is a break in the epithelium, or it is the orifice of an evagination" The metapore was discovered in an adult orang and three old world monkeys. In the former there are several orifices in the metatela. The apertures were of two varieties, viz., one in which the metaplexuses barely project at the margins, the other in which they extend for some distance upon the cerebellum.

According to Blake (1), the metapore arises by a developmental tearing of the caudal protrusion of the inferior part of the tela chorioidea. His notable contribution is based on microscopic study of adult and embryonic brains, both in man and lower animals. Blake accounts for the foramina by maintaining that in mammals there is a tendency for absorption of ventricular expithelium unless it is supported by nervous tissue or pia of neighboring structures.

The boundaries of the posterior median aperture, described by Blake, are those given by Key and Retzius, namely the chorioid plexus above, the membranous epithelial walls on either side, and the posterior margin of the obex below if present, otherwise the ligula. Variability depends on the amount of absorption of the epithelial tube during early development. He contends that the lateral recesses are formed by the lateral portions of the roof of the rhomboidal fossa when the pons flexure is completed. This is slightly caudal to the widest breadth of the roof.

Hess (5) states that in the fetus the roof of the fourth ventricle is never closed; furthermore large communications are demonstrable in the fifth month pre-natal specimens, and very likely exist at an earlier period. In the adult brains he found orifices in the roof and in the lateral recesses; these were apertures in the pia mater.

In the late nineteenth century, Morton (12) investigated the communication of the fourth ventricle with the subarachnoid space. He directed his efforts to normal and pathological brains i.e., fourteen cases of tuberculous meningitis. A special method of dissection, which he used, avoided removal of the brain from the cranium. He described the porterior median aperture saying, " it is a broad slit or larger space reaching from the cerebellum above to the calamus scriptorius below." The lateral openings were not examined after it was established that a posterior central communication existed.

Mall (11) studied the development of the blood vessels of the brain in the human embryo with injections of india ink. The extravasation of ink was found to pass into the fourth ventricle from the subarachnoid space through a medial aperature.

Dandy (3) in his paper on " Experimental Hydrocephalus," has evidence that after occlusion of the foramina of Luschka and Magendie there is produced invariably a hydrocephalus. His work consisted in artificial blocking of the communication of the cerebrospinal fluid which forms within the ventricles.

Another publication of interest is that of Rogers and West (13) who demonstrated the findings in vivo. There men made observations when operating in the posterior fossa of the skull and correlated their work with dissections of the suboccipital region, retaining the brain and its coverings in situ. ~~They~~

They found that the whole of the lower part of the Rhombencephalon was wide open so that the cavity of the hind brain was in free median communication with the cisterna magna. In fact, the foramen appears as a large defect in the lower part of the ventricular roof, the boundaries being the obex posteriorly and the ligulae posterolaterally, with the inferior medullary velum in front.

The study of the circulation of the cerebrospinal fluid is very significant in relation to the posterior median foramen. From its origin in the lateral ventricles, Jackson traces the cerebrospinal fluid through the foramina of Monro to the third ventricle, and thence along the aqueduct of Sylvius to the fourth ventricle. It then escapes through the terminal opening of Magendie and the lateral clefts of Luschka to the great subarachnoid space (cisterna magna).

Recently at the regular meeting of the Chicago Neurological Society, Dr. Freeman (4) presented a paper discussing the use of colloidal thorium dioxide, a substance of high radiopacity, in the delineation of the cerebral ventricles. Clinically he has been able to demonstrate by serial roentgenograms, that the material, after being injected into the lateral ventricles, goes rapidly through the fourth ventricle and out into the subarachnoid space, provided there are no obstructions. The passage of the colloid corresponds to the cerebrospinal fluid circulation given by Jackson.

In 1931 Miss Chapman (2) of Loyola submitted a thesis on the foramen of Magendie after microscopic work on brains of human fetuses and adult monkeys. Her paper described a foramen in the roof of the fourth ventricle, in the region known as the obex. Furthermore, the tela and the chorioid plexuse were found to end definitely in connection with the pia of the vermis near the caudal termination of the ventral surface of the cerebellum. She described the ependymal lining of the floor of the fourth ventricle ending abruptly at a point caudal to the entrance of the central canal into the fourth ventricle.

, Weed (16) expressed his idea clearly when he stated that the mode of escape of the cerebrospinal fluid from the fourth ventricle into the subarachnoid spaces was still questioned, but, the existence of the foramina of Luschka between the lateral recesses and the cisternae was not controverted.

In his later work (1917) he said, " There is no evidence that functional communications between the cerebral ventricles and the subarachnoid spaces exist in any region except from the rhombic ventricle."

Methods

It was thought advisable to dissect specimens of human adult brains. At first, dissection was done in the vicinity of the cerebellar tonsils and the obex region. Later the technique was modified. The fourth ventricle was filled with a stained coagulum of celloidin or gelatin which served as a guide to dissection, as well as a mold to prevent possible tears during the course of work.

In the preparation of the material, it should be mentioned that the coagulating substance was introduced without disturbing the relations in the region of the possible foramina. The brain, after removal, was cut transversely through the rostral part of the pons, after which the entire caudal portion of the brain stem, including the cerebellum was separated carefully. In the rostral part of the fourth ventricle there was now an aperture through which the coagulating solution was dropped gently, filling the ventricle and allowing the fluid to exude caudally through any possible channels of escape.

The procedure just described was used also in preparing sections for microscopic study. After the usual methods of fixation in formalin and suitable dehydration in graded alcohols, the nerve tissue was embedded in celloidin or more rarely in paraffin. Hematoxylin and eosin staining was employed at all times.

From a transverse series of serial sections, a model was reconstructed by the method of Dr. Strong (15) to present in three dimensions, the region in relation to the rhombic lips and the obex of the fourth ventricle.

Because of the criticism of injury by removal from the cranial cavity, it was thought appropriate to section fetal heads of the proper age with the brain in situ. For this purpose the skulls of feasible fetuses were decalcified and then prepared by our usual routine for microscopic slides.

Results

Extreme care is necessary to determine whether or not a posterior median aperture of the fourth ventricle exists. The character of the tela chorioidea of the pars inferior of the ventricle must be determined. In our studie s, fetal and adult brains were examined in the region of the caudal limit of the tela chorioidea of the fourth ventricle, and the relations were observed carefully.

In all cases the tela chorioidea is attached to the lateral margins of the rhomboid fossa in its major part. However, at the caudal termination of the fourth ventricle, dorsal to the rhombic lip and the obex, the tela is adherent to the vermis of the cerebellum, and the chorioid plexus protrudes caudally. In Sections of transverse and sagittal series of adult brains, figures B-1, 2, 3 and C-2, the fourth ventricle is seen with the tela chorioidea attached to the medulla except at its caudal end. Sections of the caudal portion of the fourth ventricle reveal the tela chorioidea separated from the dorsum of the medulla and attached to the ventral surface of the cerebellum. Figures A-1; B-4, 5, 6, 7, 8; C-3. The section shown in figure B-4 is related to a transverse plane in figure A-1 at the level indicated by the separation of the medulla and the tela chorioidea. Figures B-5, 6, 7, and 8 are sections caudal to figure B-4. Figure C-3 is of a section indicating the mid-sagittal plane of figure A-1. The rhombic lip and obex which are not joined by the roof membrane of the ventricle, form the letter " V ", the apex representing the region of the obex. Figures A-1 and C-3. In figures B-4, 5, 6, 7, 8, the rhombic lip is seen as it appears in transverse sections while in figure C-3, the obex region is seen in mid-sagittal section. At the base of the " V " - shaped rhombic lips, the limb on each side forms an acute angle with the separated tela chorioidea which appears like a protruding lip and is designated the " roof - lip" of the fourth ventricle. The caudal protrusion of the chorioid plexus in figure A-1 is the"roof lip". Transverse sections of the"roof lip" are observed in figures B-4, 5, 6, 7, 8, and D-4. Figures C-3 and E-1, 2 display the " roof lip " in the sagittal plane. Serial sections reveal a definite separation of the tela chorioidea from the medulla in the rhombic lip region. (See figures B-4, 5, 6, 7, 8)

Because Hess (5) and Kollman (9) found a break in the rombic roof between the third and fifth months of prenatal life, it was considered advisable to prepare serial sections of fifth and sixth month fetal brains. A,transverse and sagittal series of sections were prepared for study. The brains were not removed from the cranial cavity for fear that artefacts might occur.

The findings in the fetal specimens correspond fully with those observed in the adult except that the development of the related structures, the medulla and cerebellum, has not assumed the extent found in later life.

In figures D-2 and E 1, 2, the central canal may be observed to communicate with the floor of the fourth ventricle, just rostral to the obex region. The cisterna magna (sub-arachnoid space) is shown in figures D-1, 2, 3, and E-1, 2.

The fourth ventricle is not overlapped by the cerebellum as in the adult. The rhombic lip is continuous with the tela chorioidea in the rostral portion of the ventricle. This is indicated in figure D-4 by the taenia of the ventricle. As in the adult, the tela chorioidea is separated from the dorsum of th the medulla caudal to the base of the " V " shaped rhombic lip. Figure E-1, 2. The Foramen is comparatively larger than in the adult. Figures E-1, 2 and D-1,2,3,4.

Figure E-2 shows a section slightly lateral to the mid-sagittal plane (fig.E-1). It involves a transition from the obex to the rhombic lip. The central canal is observed to be less distinct than in figure E-1 because the lateral margin of the canal is sectioned. The Arachnoid membrane is in an excellent state of preservation in the same section, extending from the extreme caudal part of the cerebellum to the caudal end of the medulla. The membrane encloses the subarachnoid space (cisterna magna) with a posterior convexity coinciding with the concavity of the posterior fossa of the skull.

The chorioid plexuses are observed to protrude ventrally from the lateral recesses and are related dorsally to the flocculus. Figures D-4, 5. In figure D-5 the lateral recesses of Luschka are apparent.

An attempt was made with a number of specimens to overcome any criticism that a posterior median aperture is due to tears in manipulating the tissues. A stained coagulating solution was introduced carefully through the cerebral aqueduct (Sylvius) previous to sectioning. The coagulating solution was allowed to trickle through the ventricle, drop by drop, so that no pressure, causing the membrane to rupture, was exerted upon the tela chorioidea. The coagulum could be seen exuding into the subarachnoid space and later forming a mold which retained the tissues in their original position. Figures C-1, 2, 3, show the red-stained coagulum within the fourth ventricle, the lateral recesses and the subarachnoid space (cisterna magna). In a mid-sagittal section (figure C-3) the coagulum is seen to occupy the space between the terminal free chorioid plexus ("roof lip")above and the obex below. Since the coagulum was introduced carefully into the cerebral aqueduct, and allowed to flow through the fourth ventricle drop by drop, it is evident that the coagulum in the subarachnoid space of necessity passed through an aperture in the caudal portion of the fourth ventricle. The coagulating solution was never introduced with sufficient pressure to cause a tear in the delicate tela chorioidea.

The work presented leads one to believe that the tela chorioidea is not attached to the medulla in its entire extent, but instead there exists a separation in the inferior part of the fourth ventricle. As a result the fourth ventricle communicates with the great subarachnoid space.

A model, reconstructing the region of the posterior median foramen of the fourth ventricle, shows clearly the boundaries of the aperture. The tela chorioidea as the "roof lip" forms the dorsal boundary, the " V " shaped rhombic lips, the floor of the fourth ventricle and the obex, the ventral boundary, while there exists laterally the interval of separation between the tela chorioidea and the margins of the rhombic lips. The aperture communicates with the subarachnoid space caudally in the direction of the obex, and laterally through the separation between the tela chorioidea and the rhombic lips.

Conclusion

It may be stated in conclusion that the posterior median foramen (Magendie) is not an artefact but a true, anatomical communication.

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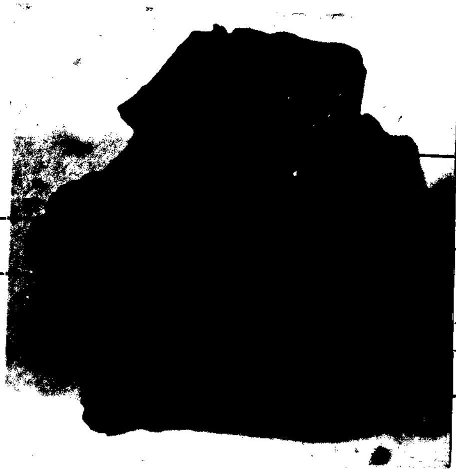
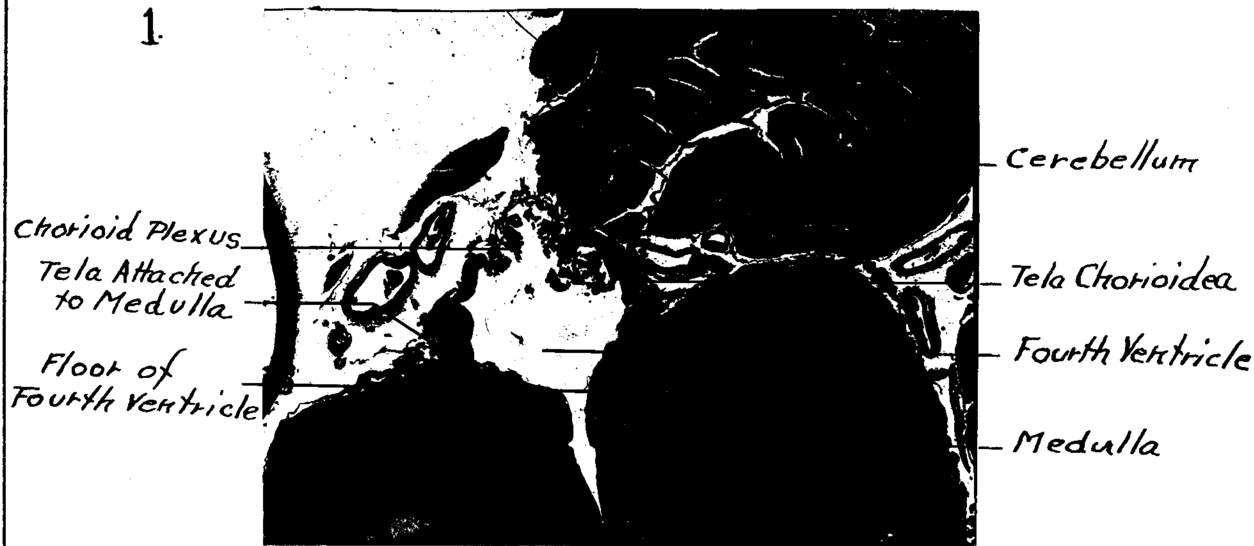
A. Gross Dissection of Posterior Median Foramen (Adult Brain)

1.



B. Transverse Sections of Adult Brain*

1.



X 5.0

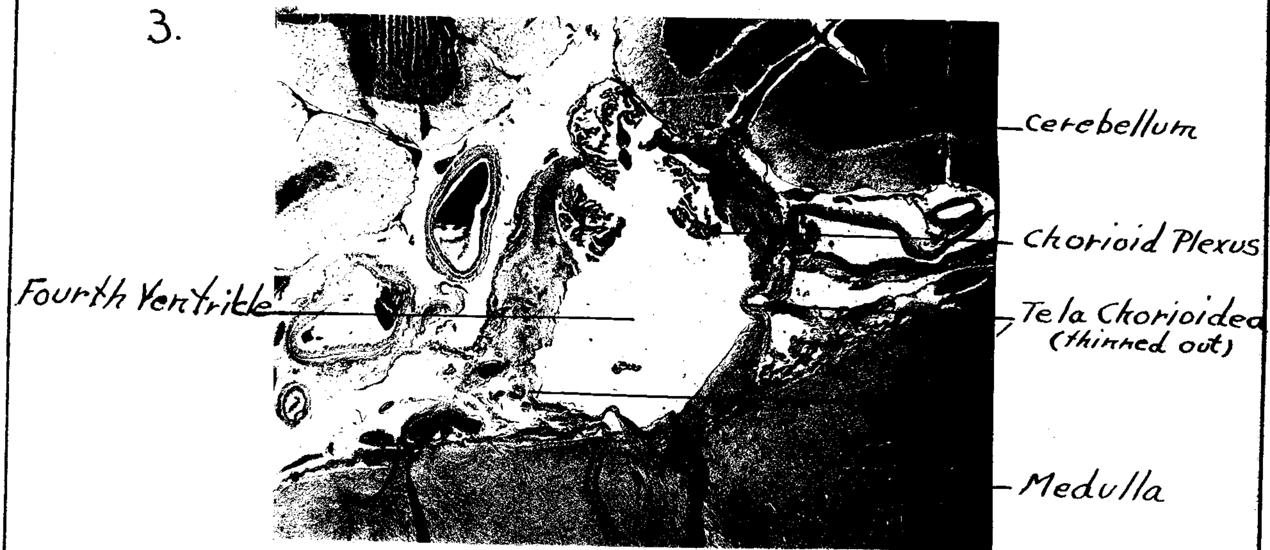
Greater Magnification of B-1

2.

X 8.3

B. Transverse Sections of Adult Brain

3.



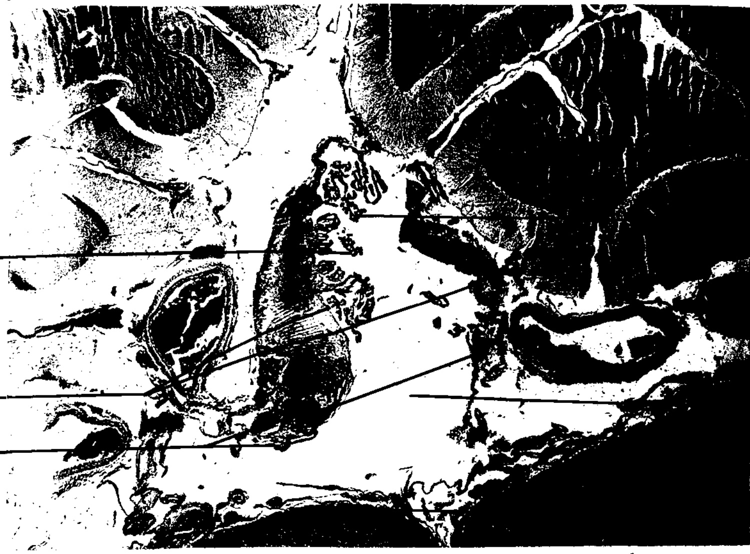
X 8.3

4.

X 8.3

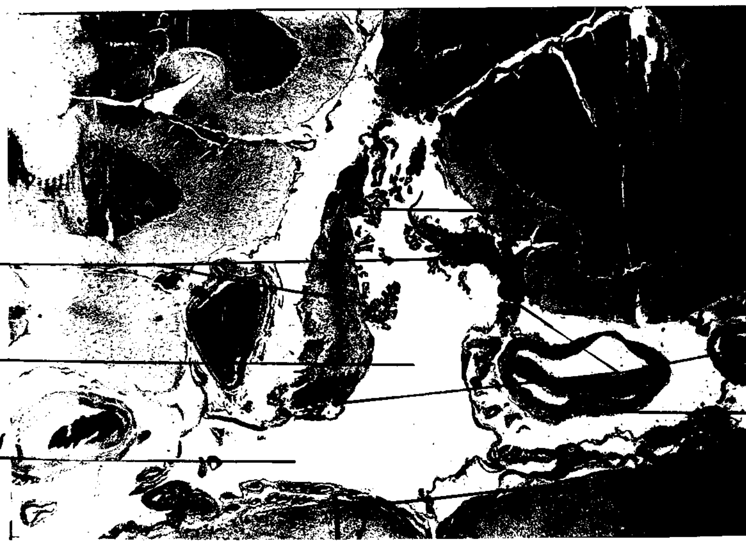
B. Transverse Sections of Adult Brain

5.



× 8.3

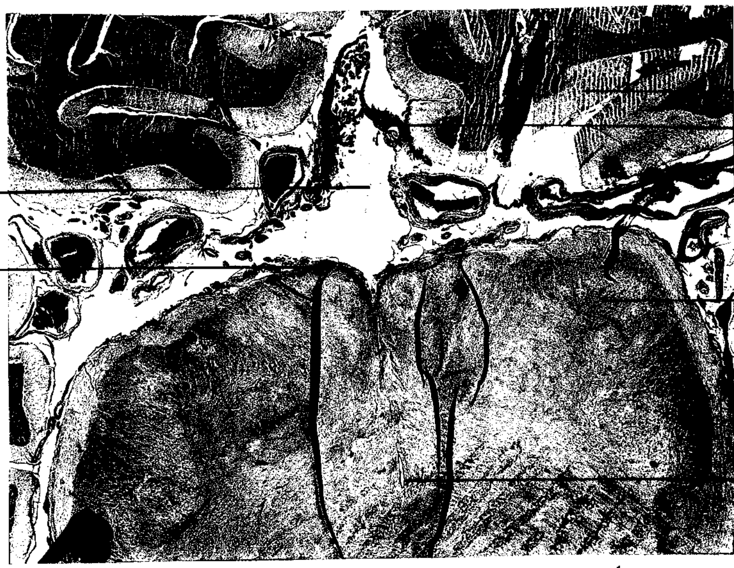
6.



× 8.3

B. Transverse Sections of Adult Brain

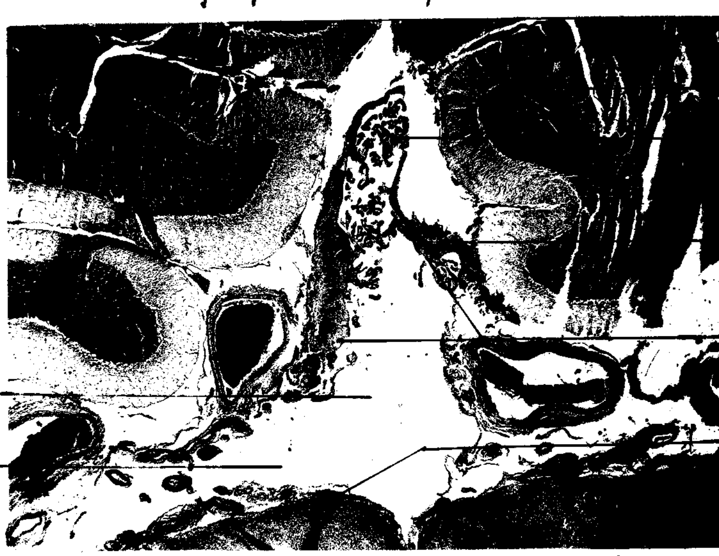
7.



X 5.0

Greater Magnification of B 7.

8.



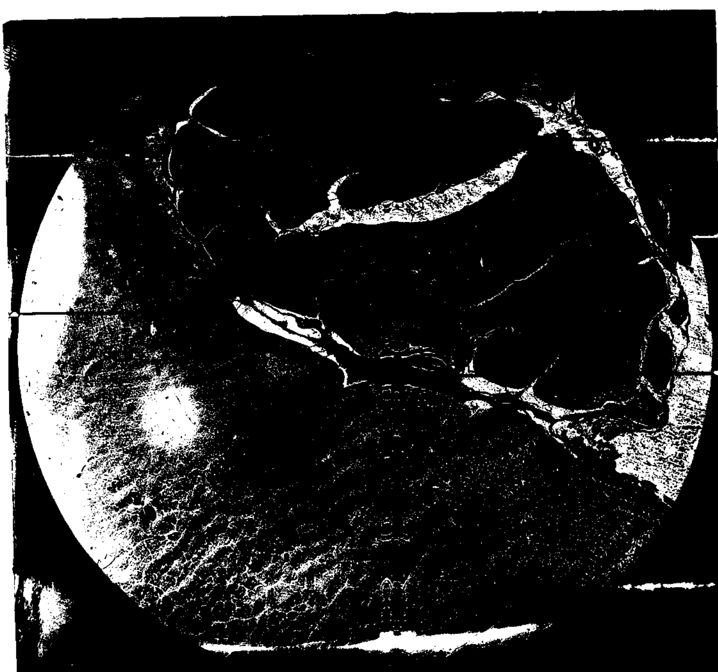
X 8.3

C. Sagittal Sections of Adult Brain

1.

X 3.7

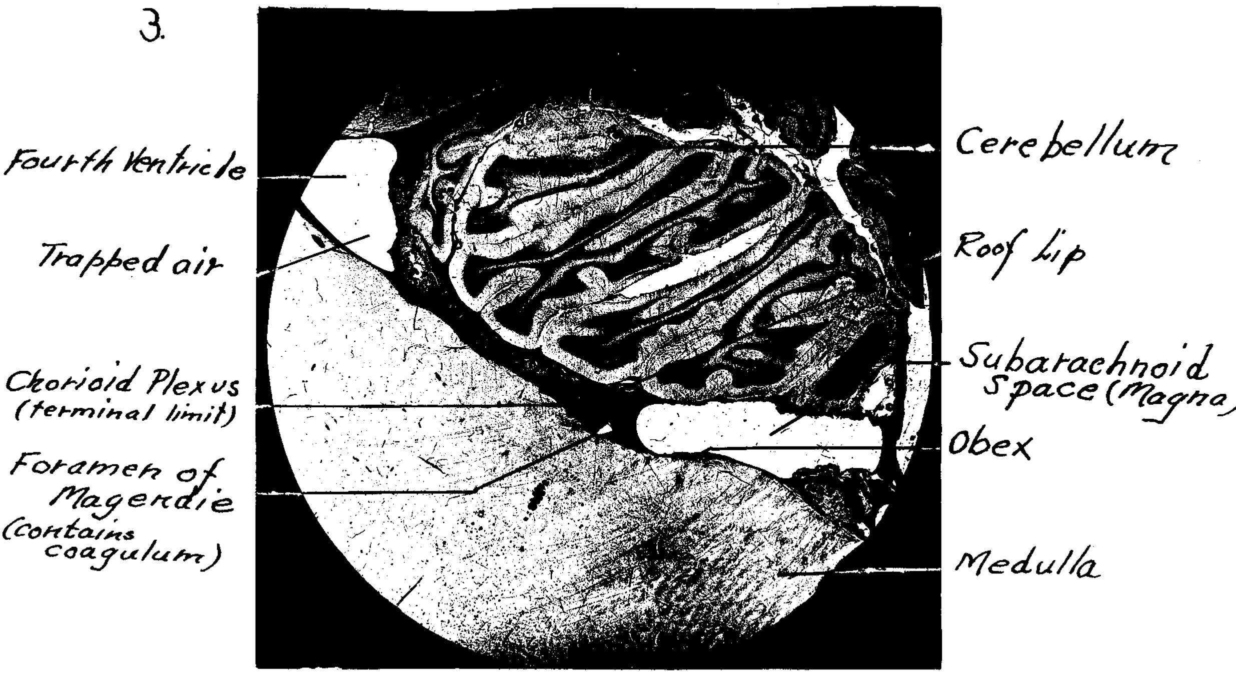
2.



X 3.7

C. Sagittal Sections of Adult Brain

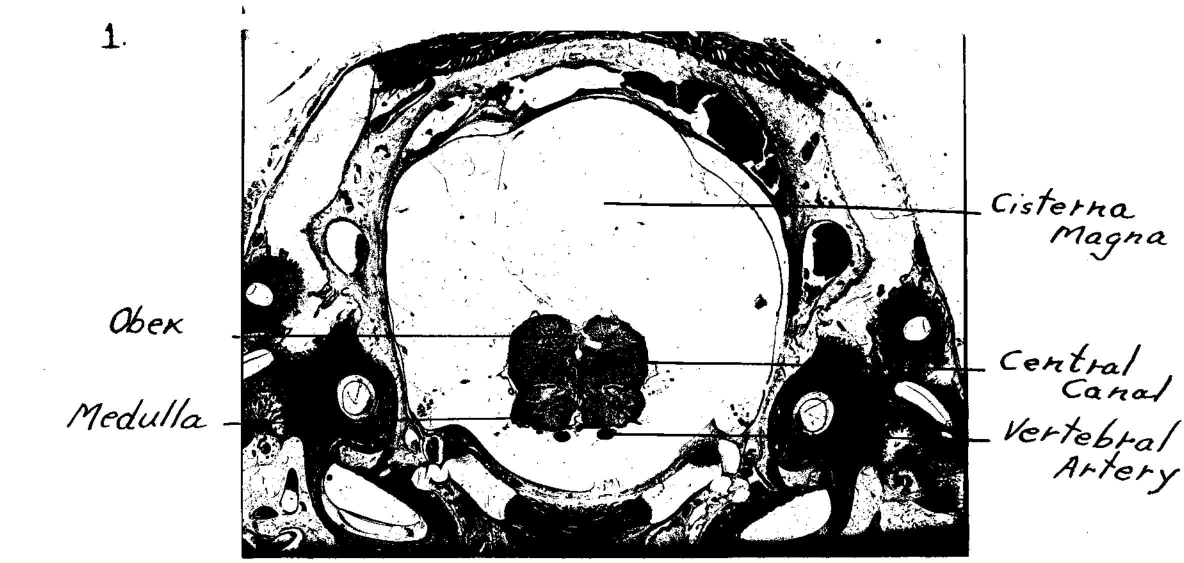
3.



X 3.7

D. Transverse Sections of Fetal Brain in Situ
(5th month)

1.



X 3.1

2.

X 3.1

D. Transverse Sections of Fetal Brain in Situ (5th month)

3.

X 3.1

4.

X 3.1

D. Transverse Sections of Fetal Brain in Situ (5th month)

5.

X 3.1

E. Sagittal Sections of Fetal Brain in Situ
(6th month)

1. Mid-Sagittal Plane

X 3.1

2. Transition from Obex to Rhombic Lip

X 3.1